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METHOD OF CONCEALING AN IMAGE

Field of the Invention

5   The present invention relates to a method of
creating a security image in which at least one image is
concealed. In one embodiment an encoded image is
concealed within a visible image. Embodiments of the
invention have application in the provision of security
10   devices which can be used to verify the legitimacy and
presence of a document or instrument, for example a credit
card. Other embodiments can be used to provide novelty
items which are protected against counterfeiting.

15   Background to the Invention

In order to authenticate and verify the
originality of, and to prevent unauthorised duplication or
alteration of documents such as banknotes, credit cards
20   and the like, security devices are often incorporated.
The security devices are designed to provide some proof of
authenticity and deter copying. Despite the wide variety
of techniques which are available, there is always a need
for further techniques which can be applied to provide a
25   security device.
A variety of techniques have been developed to
conceal latent images within security documents and
instruments. Perhaps the earliest such technique is the
Watermark. In this approach, a latent image is provided
30   on a paper substrate such that the image is invisible when
the paper is viewed in reflection, but visible when it is
viewed in transmission.
A more recent means of concealing images for
security applications is known broadly as "Modulated
35   Digital Images" (MDI). As noted by Amidror (Issac
Amidror, "The Theory of the Moiré Phenomenon", Kluwer
Academic Publishers, Dordrecht, 2000, pages 185-187), when

two locally periodic structures of identical periodicity
are superimposed upon each other, the microstructure of
the resulting image may be altered (without generation of
a formal Moiré pattern) in areas where the two periodic
5   structures display an angle difference of $\alpha = 0°$. The
extent of the alteration in the microstructure can be used
to generate latent images which are clearly visible to an
observer only when the locally periodic structures are
cooperatively superimposed. This principle forms the
10   basis of several techniques for concealing or encoding
latent images by modulating periodic structures. These
latent images can only be observed when they are
superimposed upon a corresponding, non-modulated
structure. Accordingly, a modulated image can be
15   incorporated in an original document and a decoding screen
corresponding to the non-modulated structure used to check
that the document is an original – e.g. by overlaying a
modulated image with a non-modulated decoding screen to
reveal the latent image.
20   While such techniques are themselves useful,
where the presence of such images can be detected, there
is a risk that malicious parties will develop techniques
for decoding such images or replicating them.
Accordingly, it would be desirable to provide a technique
25   which is suitable for concealing at least modulated
digital images and preferably other image types as well.

Summary of the Invention

30   The invention provides a method of forming a
security image from two or more images comprising:
             manipulating tonal values of each image element
of a first image to take values within a first set of
tonal values;
35   manipulating tonal values of each image element
of a second image to take values within a second set of
tonal values; and

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forming a security image from the manipulated tonal values of the first and second images, the first and second sets of tonal values being selected so that at least one of the first and second images is concealed in
5　the security image.

The tones may be grey scale tones or colour tones.

In one aspect, the invention is used to conceal an encoded image within a visible image. In this
10　embodiment, the first image is a visible image and the second image is an encoded image which can be decoded using a decoding screen, the encoded image being the image concealed in the security image. There may also be additional visible or encoded images.

15　The encoded image is typically a digitally modulated image.

The method may involve converting a latent image to obtain an encoded image.

In this embodiment, it is preferred that the
20　first set of tonal values is larger than the second set of tonal values. Preferably the ratio of the first set of tonal values to the second set of tonal values is in the range of 55:45 to 80:20 and more preferably in the range 60:40 to 70:30.

25　It is preferred that the sum of the number of tones in the first and second sets is equal to the number of available tones for the image representation technique.

In one embodiment, each of the first and second sets of tonal values are ranges of sizes whose sum is
30　equal to the number of available tones in the range of tones for the image representation technique. In this embodiment it is preferred that each of the first and second images are full tone range images and that each of the first and second images are manipulated by
35　proportionally compressing the values of the tones to take values within the first and second ranges. The image may then be formed by adding the tonal values of corresponding

image elements. These combined image elements take values
within the full tonal range. By way of example, where the
original tonal range is 0-255 of grey-scale tones, the
first image may be compressed to 0-179 and the second

5   image may be compressed to 0-76. The added tonal values
are added to take values between 0-255.

In another aspect, the invention is used to
conceal a plurality of images within a security image in
such a manner that they can each be decoded by a

10 processing means.

This embodiment is particularly suited to
combining a plurality of two tone images including at
least first image and second image, by allocating each
image element of each two tone image one of the values of

15 the bit, and

wherein the security image is formed by adding
the values of the respective bits to obtain a grey scale
value for each image elements.

Thus, in this embodiment, segments (e.g. bits) of

20 a code for defining the tonal value (e.g. a grey scale
value) of each image element are allocated as the sets of
tonal values for respective ones of the plurality of
images so that the segments can be combined to form a
composite tonal value of each image element without

25 disturbing the values of the segments so they, and hence
the plurality of images, can be decoded.

The invention also extends to security devices
incorporating security images made in accordance with the
above methods.

30 Such security devices may be stand alone devices
or may be incorporated as parts of documents, instruments
etc. - for example, they may be used in passports,
security cards, credit cards and bank notes.

Accordingly, the invention provides a security

35 device comprising:

a security image formed from manipulated tonal
values of first and second images, the first and second

images being manipulated to take values within the first
and second sets of tonal values, the sets of tonal values
being selected so that at least one of the first and
second images is concealed in the security image.

5   The term "security image" is used to refer to an
image which contains one or more concealed images. It
will be appreciated that the concealed image need only be
in a portion of the area of the security image. As tones
are manipulated to conceal the images, these security

10   images are also referred to as "Tonagrams".

In this specification, "Image elements" refer to
image portions which are manipulated collectively.
Typically, these will be pixels, however, they may be
groups of pixels (e.g. a 2 x 2 matrix of pixels),

15   depending on the desired resolution and reproduction
technique.

In this specification, any image or images used
in the formation of a security image which are intended to
be readily apparent to an observer in a finished security

20   image are referred to as "visible images".

Similarly, images used in the formation of a
security device which are to be encoded and hidden in the
security image are referred to as "latent images" – the
latent images are intended to be visible once decoded.

25   Once the latent images have been encoded, for
example using a MDI algorithm such as that employed to
make a Phasegram, Binagram or μ-SAM, the images are
referred to in this specification as "encoded latent
images" or "encoded images".

30   Once visible images are manipulated to take
values within a set of tonal values different to those
used to initially represent the visible images they are
referred to in this specification as "tonal visible
images".

35   Similarly, when the tonal range of encoded latent
images have been manipulated, the resulting images are
referred to as "tonal encoded latent images" or "tonal

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encoded images".

However, it will be appreciated that these tonal
images do not necessarily have to be produced and that the
security image can be formed directly from the tonal

5   values.

"Concealed images" are the latent images which
have been hidden and cannot be observed without a decoding
operation. Typically, the concealed image will be an
encoded image and the decoding operation will be

10   overlaying the security image with a decoding screen.

Further features of the invention will become
apparent from the following description of preferred
embodiments of the invention.

15   Brief Description of the Drawings

Preferred embodiments of the invention will be described
with reference to the accompanying drawings:

20   Figure 1 depicts a visible grey scale image of
the first embodiment of the invention in a full tonal
range of 0-255 tones,

               Figure 2 depicts a black and white BinaGram of
the latent image of the first embodiment of the invention

25   covering the full tonal range of 0-255 tones,

               Figure 3 depicts the appropriate MDI screen which
reveals the latent image when overlaid upon Figure 2,

               Figure 4 depicts Figure 1 restricted to the tonal
range 0-179 (that is, the compressed image V1)

30   Figure 5 depicts Figure 2 restricted to the tonal
range 0-76 (that is, the compressed image H1),

               Figure 6 depicts the additive combination of
Figure 4 and Figure 5. The resulting Tonagram T1 contains
the full tonal range of 0-255 tones,

35   Figure 7 depicts the image observed when the MDI
screen in Figure 3 is overlaid upon Figure 6.

               Figure 8 depicts a colour picture containing 256

tones of three primary colours (providing approximately 16 million colour combinations). This is the visible image of the second example of the first embodiment of the invention,

5   Figure 9 depicts the resulting Tonagram combination of Figure 8 and Figure 3 in the ratio 60%:40% respectively,

          Figure 10 depicts the Tonagram of Figure 9 partially overlayed with the screen in Figure 3,

10   Figure 11 depicts a Tonagram consisting of a black-and-white visible image combined with an identical, but coloured MDI Binagram,

          Figure 12 depicts the Tonagram in Figure 11 partially overlaid with the MDI screen in Figure 3,

15   Figure 13 is a schematic depicting the process of forming a Tonagram containing several images and the method of extracting one of the images from the Tonagram.

Description of the Preferred Embodiments

20

First Embodiment

          Any digital system employed to depict continuous tone images has to reduce the number of shade levels to a
25   discrete number. This applies to both grey scale and colour images. According to one standard (8 bit), the range of shades employed is 256, numbered from 0 to 255 and defined as levels of light output from a computer monitor. Hence in a grey scale depiction, 255 is white and
30   0 is black. Using the red-green-blue (RGB) colour system, (255R, 255G, 255B) is white and (0R, 0G, 0B) is black (i.e. there are 8 bits for each of red, green, and blue). Other standards incorporate 65,536 tones (at least for grey; 16 bit standards) and 4096 tones (12 bit standard).
35   Similar standards are used for other colour separation techniques such as CYMK.

          The central principle of the first embodiment of

the present invention is to form a security image which
unobtrusively combines one or more visible images with one
or more concealed latent images by partitioning each of
the visible and latent images into selected tonal ranges

5   and then combining them into a single security image using
a suitable algorithm. The effect of reconstituting an
image into a reduced tonal range is to lessen the colour
range or contrast visible in the image. The image
therefore adopts an increasingly "washed-out" appearance

10 as its tonal range is decreased. An image partitioned
into a wide tonal range will therefore be more clearly
visible and distinct than one constituted within a narrow
tonal range. Thus, when a visible image, portrayed in a
relatively wide tonal range, is combined with a latent

15 image encoded using a modulated digital image (MDI)
technique and portrayed in a narrower tonal range, the
latter may become exceedingly difficult to see against the
more clearly distinct background of the former. This
concealment is amplified by the nature of most MDI encoded

20 latent images, which typically have a uniformly grey or
intermediate colour appearance. When the security image
is overlaid with the appropriate MDI decoding screen
however, the latent image is revealed as a result of the
selective silhouette produced by the screen. In this way

25 it becomes possible to conceal latent images incorporated
within clearly visible images.

        To most successfully implement this technique, a
choice is required in the tonal ranges employed for the
visible and the latent image. In order to make the

30 visible image highly obvious, a large tonal range is
desirable. The same is true for the latent image, which
is ideally also constructed with a large tonal range.
However, the latent image is more effectively concealed
against the background of the visible image, when the

35 tonal range of the visible image is large relative to that
of the latent image.

        In order to maximise the contrast and visibility

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of both the visible image (under ambient conditions) and
the latent image (when overlaid with a screen), a large
tonal range is required. A security device having a
security image of this type will consequently typically
5   employ the full tonal range available for the method of
display or reproduction employed. Since a limited tonal
range exists for any one method of displaying an image, a
complementarity in the tonal ranges of the visible and the
latent image must occur in such a case. That is to say,
10   if the entire tonal range is cumulatively employed, then
increasing the tonal range of the visible image means that
the tonal range of the latent image must decrease
correspondingly. The cumulative number of tonal ranges
present in the tonal visible images and the tonal
15   concealed latent images may not exceed the maximum number
of tones available in the method of image representation
employed. In the optimal case, the tonal range used for
the visible image will be large enough (both in absolute
terms and relative to the tonal range of the latent image)
20   to make the visible image highly obvious under ambient
conditions while simultaneously concealing the latent
image effectively. However, the tonal range of the
visible image must not be so large as to cause the latent
image to have so narrow a tonal range as to be
25   indistinguishable when overlaid with the appropriate MDI
screen. An effective device therefore requires a careful
balance in the competing requirements of clear visibility
of the latent image when overlaid with an appropriate MDI
screen, but clear concealment against the background of
30   the visible image in the absence of the MDI screen.

            There are a number of MDI techniques which can be
used with the present invention. One such technique,
known as Screen Angle Modulation, "SAM", or its micro-
equivalent, "µ-SAM", is described in detail in US patent
35   number 5,374,976 and by Sybrand Spannenberg in Chapter 8
of the book "Optical Document Security, Second Edition"
(Editor: Rudolph L. van Renesse, Artech House, London,

1998, pages 169-199), both incorporated herein by
reference. In this technique, latent images are created
within a pattern of periodically arranged, miniature
short-line segments by modulating their angles relative to
5   each other, either continuously or in a clipped fashion.
While the pattern appears as a uniformly intermediate
colour or grey-scale when viewed macroscopically, a latent
image is observed when it is overlaid with an identical,
non-modulated pattern on a transparent substrate.

10   We have developed another technique of this type
which we refer to as a PHASEGRAM described in Australian
provisional application number 2003905861, entitled
"Method of Encoding a Latent Image", filed
24 October 2003, and also disclosed in PCT/AU2004/000915
15   filed 7 July 2004, the disclosure of which is incorporated
herein by reference. In this technique, an image is
encoded within a locally periodic pattern by selectively
modulating the periodicity of the pattern. When overlaid
upon or overlaid by the original pattern on a transparent
20   substrate, the latent image or various shades of its
negative becomes visible to an observer depending on the
exactness of the registration.

We have also developed a further technique of
this type which we refer to as a BINAGRAM which is
25   disclosed in Australian provisional application number
2003902810, entitled "Method of Encoding a Latent Image",
filed 4 June 2003, and also disclosed in PCT/AU2004/00746
filed 4 June 2004, the disclosure of which is incorporated
herein by reference. In this technique, an image is
30   divided into pairs of adjacent or nearby pixels, which may
be locally periodic or not. One of the pixels in each
pair is then selectively modulated to the complementary
grey-scale or colour characteristic of the other pixel.
Because of the presence of equal quantities of
35   complementary pixels, a BINAGRAM has a uniform grey- or
intermediate tone when viewed macroscopically. However,
when overlaid upon or overlaid with an equivalent

non-modulated pattern on a transparent substrate, the latent image or its negative becomes visible depending on the extent of registration.

5   The technique of the first embodiment is now explained further using a series of examples. In each example, a single visible image is combined with a single encoded latent image. The preferred embodiment can be applied to a variety of encoded latent image types. Without limiting the generality of this embodiment, a

10   Binagram MDI image is employed for illustrative purposes in the examples of the embodiment described below. A Binagram contains, by definition, only 2 tones; usually black and white.

Further details on producing a Binagram can be

15   found in International patent application number PCT/AU2004/000746 entitled: "Method of Encoding a Latent Image", lodged 4 June 2004. Details of other techniques such as μ-SAM, and PHASEGRAM can be found in US 5,374,976 and International patent application PCT/AU2004/000915

20   entitled "Method of Encoding a Latent Image", patent application number: 2003905861 (24 Oct 2003) respectively.

The first example of this embodiment describes the use of a black-and-white visible image and a black-and-white latent image. For this example the full

25   tonal range will be considered to be 0-255 in a grey scale for illustrative purposes. The range 0-179 will be used for the visible image. This leaves the range 0-76 for the latent image (since 179 + 76 = 255). These ranges have been chosen merely to demonstrate the technique.

30   Optimisation of the resulting security image will, as noted earlier in this specification, typically involve iteratively varying the respective tonal ranges used for the visible and latent image in order to achieve the best overall effect.

35   The ranges selected for this example correspond to approximately 70% of the total tonal range for the visible image and 30% for the hidden image. These

proportions while effective for many images, can be varied
to suit the images employed, the number of images and the
application.

The visible image shown in Figure 1 is

5   manipulated by being compressed from 0-255 tones to 0-179
tones using the contrast and brightness controls in a
typical image processing software package, or specialised
software developed for the purpose or photographically or
other means known to the art. The manipulated tone value

10 of each pixel of the original visible image (T_{OLD}^{vis}) then
becomes a new tone value (T_{NEW}^{vis}):

$$T_{NEW}^{vis} = T_{OLD}^{vis} \times 179/255$$

15   The resulting tonal visible image is called V1
and is shown in Figure 4. While the compression is
performed proportionally in this particular case, other
techniques can be used. Other mathematical relationships
could be employed to compress the tonal ranges of both

20 images, for example in conjunction with a mathematical
relationship to combine the images depending on the
application. Such relationships may provide added
advantages in particular applications.

The encoded latent image of Figure 2 is

25 manipulated by being compressed from 0-255 tones to 0-76
using the contrast and brightness controls in a typical
image processing software package, or specialised software
developed for the purpose or photographically or other
means known to the art. For this example the tone in each

30 pixel of the original latent image (T_{NEW}^{lat}) becomes replaced
by a new tone (T_{OLD}^{lat}) calculated by the formula:

$$T_{NEW}^{lat} = T_{OLD}^{lat} \times 76/255$$

35   The resulting tonal encoded image is called H1
and is depicted in Figure 5,

The images are now summed tonally into a security

image. This means that wherever two pixels T_{NEW}^{lat} and T_{NEW}^{vis}
overlap, they are combined into a new pixel having the
tone T_{TON} , where

5

$$T_{TON} = T_{NEW}^{lat} + T_{NEW}^{vis}$$

The resulting security image is the Tonagram, T1,
which is shown in Figure 6. When overlaid with the
appropriate MDI mask (Figure 3), the latent image is
10 revealed superimposed upon the visible image (Figure
7) - i.e. the mask decodes the latent image sufficiently
for the existence of the latent image to be perceived.
For example, the nose 11, mouth 12, and left eye 13 of the
girl in the latent image are now perceivable.
15   The second example of this embodiment describes
the use of a colour visible image and a black-and-white
latent image. A colour image reproduced as a grey scale
image in Figure 8 was employed as the visible image and
the binagram shown in Figure 2 was used for the encoded
20 latent image. In this example the three primary colours
(red, green, blue) were scaled to 60% of the full tonal
range (tones 0-153) and the latent image was scaled to 40%
of the full tonal range (tones 0-101). The tonal visible
image and tonal encoded latent image were then additively
25 combined to give Figure 9. It will be appreciated that
the use of colour tends to draw the observer's eye away
from the "shadow" left by the encoded image. Figure 10
illustrates this Tonagram with a partial overlay of the
MDI screen in Figure 3. The unscreened area 20 has a
30 shadow whereas, in the screened area 21, the girl is
visible. The latent image is thus made visible as a black
and white image superimposed on the colour image.
Colour binagrams can similarly be combined with
grey scale or coloured images.
35   In a third example of this embodiment, a black-
and-white visible image is combined with an identical,
colour MDI latent image using the method of the second

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example of this embodiment above. The resulting Tonagram
is shown in Figure 11. The latent image is not visible
because it is identical to the visible image. However
when the Tonagram in Figure 11 is overlaid with the MDI

5   screen in Figure 3, the colour image in the screened areas
30 is revealed. Thus, the black-and-white visible image
becomes a coloured image when overlaid with the screen.
This is depicted in Figure 12.

     In an alternative approach, the sets of tonal

10   value may be kept distinct - e.g. 0-179 and 180-255 with
the security image being formed by interleaving image
elements having manipulated tonal values originating from
the first and second images respectively. In this
approach, sets could also be in the form of a plurality of

15   distinct ranges - e.g. 0-80, 125-224 and 81-124, 225-255 -
this allows a greater degree of contrast to be achieved in
the visible image.

Second Embodiment

20

     A Tonagram may encode and conceal more than one
continuous tone image. Separation of the latent images
from the security image however requires electronic or
mathematical computations based on a suitable algorithm,

25   with the resulting security images decoded by a computer
or dedicated device developed for the purpose, rather than
using an overlaid screen.

     If the display technology employed permits a
number of hues or primary colours, each with a tone range,

30   then each hue can be used independently to contain a
single grey scale continuous tone image in conjunction
with other 2-tone latent images or a multiple of 2-tone
images.

     The 2-tone latent images may be produced by

35   dithering, half-toning, hatching or using some other means
by which an image is rendered in two tones. Even dithered
coloured images may be adapted to this embodiment.

Modulated digital images and other synergistic latent images like Binagrams and Phasegrams are two tones per hue and are readily integrated to form multiple latent image Tonagrams.

5   One way in which a multiple latent image Tonagram employing a machine-based encoding / decoding system may operate is illustrated in the following example in which an 8-bit binary code is used to address each pixel. Other multi-bit systems (e.g. 16-bit, 24-bit, or 32-bit, etc.)

10   may also be used. The following example demonstrates the use of a single binary bit or digit to contain each image. Other carefully chosen multiple bit codes could be used and even the use of non-binary sequences is possible. The sequences need to be chosen so that information is not

15   altered when the sequences are combined so that the information can subsequently be decoded from the security image.

A typical computer monitor uses an 8-bit binary code to describe the tone of each pixel on the screen.

20   Such a code contains 8 numbers, each of which can only be a 0 or a 1. For example, if a pixel has a tone 11110110, this means it contains (1×2^7) + (1×2^6) + (1×2^5) + (1×2^4) + (0×2^3) + (1×2^2) + (1×2^1) + (0×2^0). In decimal notation, this equals tone number 246. Using an 8-bit

25   binary code therefore, pixel tones can go from 00000000 (which corresponds to decimal tone 0) to 11111111 (which corresponds to decimal tone 255). Thus, a computer monitor operating using 8-bit binary coding for the tones can display 256 different tones.

30   This system can be exploited by partitioning each image in a multiple image Tonagram so that it is described by only one of the bits in the 8-bit code. For example, a 2-tone image in an 8-image Tonagram may be compressed so that all of its pixels are associated with only the first

35   numeral in the code; that is, all of its pixels are either 00000000 (darker of the 2-tones) or 00000001 (lighter of the 2-tones). This is possible since the image contains

only two tones. A second 2-tone image may be compressed such that all of its pixels are associated only with the second digit in the 8-bit binary code; that is they are either 00000000 (darker tone) or 00000010 (lighter tone).

5   A third 2-tone image may be compressed such that all of its pixels are associated with only the third digit in the code; that is all of its pixels are either 00000000 (darker tone) or 00000100 (lighter tone). This can be done for each of eight 2-tone images, up to the eighth

10   image, whose pixels will be either 00000000 (darker tone) or 10000000 (lighter tone).

To achieve this, the image elements of the first latent image must be manipulated to the tonal range of the first bit. The second latent image must be compressed to

15   the tonal range of the second bit. The third latent image must be compressed to the tonal range of the third bit. The fourth latent image must be compressed to the tonal range of the fourth bit. The fifth latent image must be compressed to the tonal range of the fifth bit. The sixth

20   latent image must be compressed to the tonal range of the sixth bit. The seventh latent image must be compressed to the tonal range of the seventh bit. The eighth latent image must be compressed to the tonal range of the eighth bit.

25   The top row 100 of Figure 13 displays eight 2-tone latent images. The next row 101 down in Figure 13 shows each of the images compressed to the above tonal ranges, with the left most image compressed to the eighth (or left most) bit, the second from left to the seventh

30   bit, and so on up to the right most latent image which is compressed to the first (or right most) bit.

When the latent images are now overlaid, their individual pixels will overlap each other. To combine the 8 images into a single image, the binary codes of

35   overlapping pixels are added. As the binary code of each pixel to be combined has either a 0 or a 1 in a unique position and 0's in all other positions, the resulting sum

will have 0's and 1's whose position corresponds to their
image number. For example, if the overlapping pixels of
the eight images are:

5   00000001 (first image)
       00000010 (second image)
       00000000 (third image)
       00001000 (fourth image)
       00010000 (fifth image)
10   00000000 (sixth image)
       01000000 (seventh image)
       00000000 (eighth image)

then the sum will be:

15

       01011011

        This signifies that the corresponding pixel in
the first, second, fourth, fifth and seventh image has the
20   lighter of its 2-tones present ("1"). However the
corresponding pixels in images 3, 6, and 8 have the darker
of their 2-tones present.

        Each pixel in the resulting 8-image Tonagram will
consequently have such an 8-bit binary code in which the
25   corresponding pixel in each of the constituent images is
shown to be darker ("0") or lighter ("1"), depending on
its position in the code.

        The left most image 102 on the bottom row of
Figure 13 displays the 8-image Tonagram of the images
30   shown at the top of that Figure. As can be seen, most of
the latent images within the Tonagram are well concealed.
In this respect, it will be appreciated that the Tonagram
of this embodiment does not employ a visible image.

        Any of the individual images making up the 8-
35   image Tonagram can be readily extracted and reconstituted
using the logical "and" command. When two binary codes
are subjected to the "and" command, they are combined

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using the following rules for each corresponding pair of binary digits:

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     0 + 0 = 0
  5  0 + 1 = 0
     1 + 0 = 0
     1 + 1 = 1
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Thus, if one wishes to extract the sixth image
10   from the 8-image Tonagram, then all pixels of the Tonagram
are mathematically subjected to an "and" operation with
the code 00100000. This has the effect of forcing all of
the digits in the answer to become 0's, except for the
digit in the sixth position, which becomes "1" if a "1"
15   existed in that position in the Tonagram pixel, or "0" if
a "0" existed in that position in the Tonagram pixel. By
this means the tones for the sixth image at each pixel is
extracted.

The process shown to the right of the 8-image
20   Tonagram in Figure 13 involves a logical and operation
with a screen 103 consisting entirely of pixels having the
code 10000000. As can be seen in the resulting image 104
(second from the right on the bottom line of Figure 13),
this results in extraction of the left most of the
25   original images (top line of Figure 13), albeit in tonally
compressed form. In the final process shown on the right
of the bottom line in Figure 13, the extracted image 105
is now decompressed (that is, is stretched into the full
tonal range), returning the original image at the top left
30   of Figure 13.

It will be apparent to persons skilled in the art
that further variations on the disclosed embodiments fall
within the scope of the invention.